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A COMPARISON OF THE RELATIVE MERITS OF BARALYME AND SODASORB,(U)
FEB 78 J R MIDDLETON
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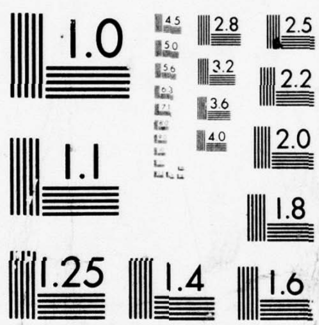

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Report No. 1-78

6 A Comparison of the Relative Merits of Baralyme and Sodasorb,

By

10 James R. Middleton

11 14 February 1978

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Glossary

ACFM	Actual Cubic Feet Per Minute
BPM	Breaths Per Minute
CO_2	Carbon Dioxide
°F	Degrees Farenheit
FSW	Feet of Sea Water
gr.	Gram
He	Helium
H.P.	High Performance
lb.	Pound (weight)
LPM	Liters Per Minute
N_2	Nitrogen
NCSL	Naval Coastal Systems Laboratory
NEDU	Navy Experimental Diving Unit
O_2	Oxygen
pH	Measure of Relative Acidity/Alkalinity
% R.H.	Percent Relative Humidity
% S.E.	Percent Surface Equivalent
SLSS	Swimmer Life Support System
SSDS	Surface Supported Diving System
UBA	Underwater Breathing Apparatus
USN	U.S. Navy

Abstract

As a result of

An NEDU study into the relative merits of Baralyme, manufactured by Chemetron Corp., and Sodasorb, manufactured by W.R. Grace Co., has shown Type A and High Performance grades of Sodasorb to be equal or superior to Baralyme in all critical performance areas including cost. It is recommended that ~~these two~~ grades of Sodasorb be approved for use as CO_2 absorbents in all Navy diving equipment.

Acknowledgements

The author would like to express appreciation to Michael F. Pratt, ENS, MC, USN and Kurt R. Raemer, ENS, MC, USN for their efforts in surveying existing literature and compiling relevant information for this report.

I. INTRODUCTION

In July 1977, NEDU was tasked by reference (1) to conduct a paper study to determine if Sodasorb would be safe for fleet wide use in manned UBA's. The results of the study, based on recent government and commercial research reports, refer only to a comparison of the currently approved CO_2 absorbent "Baralyme", manufactured by Chemetron Corporation, Medical Products Division, Stuyvesant Falls, New York and "Sodasorb", patented and manufactured by the Dewey and Almy Chemical Division of W.R. Grace Company, 5225 Phillips Lee Drive, Atlanta, Georgia. All research reports cited herein refer to one or more of the following four grades of these two products:

A. Baralyme:

(1) 12-14% water content

(2) 4-8 mesh granule size

(3) Indicator type

B. Sodasorb (Type A):

(1) 12-14% water content

(2) 4-8 mesh granule size

(3) Indicator type

C. Sodasorb (High Performance)

(1) 14-19% water content

(2) 4-8 mesh

(3) Indicator type

D. Sodasorb (Medical Grades)

(1) 14-19% water content

(2) 4-8 mesh

(3) Indicator type

Much research has been done by the U.S. Government and private industry to compare the relative merits of Baralyme and Sodasorb. Although most of this research has been directed toward specific applications other than manned UBA's, a definite pattern of repeatable and conclusive results has emerged in critical performance areas such as temperature, causticity, humidity, dusting, canister configuration and costs. Recent work on the USN MK 12 SSDS Mixed Gas Mode by NCSL has further verified other comparisons of Baralyme and Sodasorb.

II. DISCUSSION OF RESULTS

A. General

Sodasorb is the trade name for a patented sodalime material. It contains Calcium Hydroxide, Potassium Hydroxide, Sodium Hydroxide and free water. Baralyme, again a trade name, contains essentially the same chemical compounds as Sodasorb, but in different quantities plus a small amount of Barium Hydroxide. Both materials use their alkaline properties to react with any acid gas, such as CO_2. The reaction is complex and totally chemical. Absorption by physical entrapment of the CO_2 is not part of the removal process.

Each absorbent is available in three mesh sizes ranging from coarse to fine, 4 to 8, 8 to 14, and 14 to 20 respectively. The coarse mesh is used in manned diving equipment to prevent high back pressures which would increase diver breathing resistance.

Baralyme is available in only one moisture grade, 14 percent by weight. Sodasorb is available in three moisture grades:

(1) 2% Low Moisture Grade

(2) 12-14% Type A (made specifically for the U.S. Navy)

(3) 14-19% Medical Grade and High Performance

Of these only the latter two are suitable for manned diving. The 2% water grade of Sodasorb does not contain sufficient moisture to sustain the chemical reaction required in manned diving systems and will not be considered further in this report.

The 12-14% moisture grade of Sodasorb (Type A) is made to meet U.S. Navy requirements and is currently in use in many commercial and military hyperbaric chamber life support systems. Two grades of Sodasorb are available in the 14-19% moisture range, Medical Grade and High

Performance. Both are considered in this report, the difference being in the surface porosity of the granules. The High Performance grade is significantly more porus than the Medical Grade with packing densities of 80 gr. per 100cc and 86.4 gr. per 100cc respectively. The theory behind increased porosity is to increase surface area to provide more instantaneously usable reaction area per granule. This should result in greater absorbent efficiency and a more stable chemical reaction.

Indicator type Baralyme and Sodasorb both change colors as the scrubbing properties of the absorbent are diminished with use. Sodasorb changes from white to purple while Baralyme changes from pink to purple. These color changes should not be used as the final criteria in judging whether or not the absorbent is exhausted since a return to the original colors occurs after only 3 to 5 hours of non-use.

The performance of all absorbents considered herein is degraded when used at depths greater than 100 FSW. However, it has been shown in manned and unmanned air and helium-oxygen tests at NEDU that this reduction in bed life is 10-15% less than surface values. Consequently, this effect will not be considered further in this report.

B. Temperature Effects

One of the most critical performance characteristics of a CO_2 absorbent is its performance at low temperatures (below 70°F). The reaction of CO_2 with alkali metals in Baralyme and Sodasorb is temperature dependent. Consequently, as the scrubber bed temperature decreases, the rate of chemical reaction will decrease, thus decreasing scrubber efficiency. Four independent research studies are cited to give comparative results of Baralyme and Sodasorb performance at low temperatures.

(1) In reference 2, T.C. Wang conducted a surface experiment testing the effects of temperature on the two absorbents (Medical Grade Sodasorb and Baralyme). A small laboratory canister was immersed in water. Gas flow rate through the canister was low and was cooled to ambient water temperature and humidified before passing into the canister. Test parameters were as follows:

(a) Depth: 0 FSW

(b) Canister type: cylindrical

(c) Amount of absorbent: 5 grams

(d) Type of gas flow: continuous

(e) Gas flow rate: 0.280 LPM

(f) Gas mix: 1% CO_2 in N_2

(g) Gas temperature into canister: Equal to water temperature

(h) Gas humidity: 90% R.H.

(i) Water bath temperature: 40° to 70°F

(j) Breakthrough Value: 0.5 %CO_2 measured at canister outlet

The results of this test showed that Sodasorb (Medical Grade) lasted 60% longer than Baralyme at temperatures above 60°F, and 80% longer than Baralyme at 40°F.

(2) In reference 3, Jean G. Smith tested the effects of temperature on Baralyme and Sodasorb (Type A). A cylindrical canister 3.25 inches inside diameter and 10.5 inches long was used with gas entering through the bottom of the canister. The canister was immersed in a water bath and the gas was heated and humidified before entering the canister to simulate human respiration. The test parameters were as follows:

(a) Depth: 0 FSW

(b) Canister type: cylindrical

(c) Amount of absorbent: 1000 grams (2.2 lbs)

(d) Type of gas flow: continuous

(e) Gas flow rate: 12.5 LPM

(f) Gas mix: 4% CO_2 in O_2

(g) Gas temperature into canister: 98.6°F

(h) Gas humidity: 100% R.H.

(i) Water bath temperature: 35°F - 85°F

(j) Breakthrough Value: 0.5% CO_2 measured at canister outlet

Test results indicated that in 35°F temperature water, Sodasorb (Type A) lasted up to 300% longer than Baralyme before 0.5% CO_2 in the outlet gas was reached. As bath temperature increased, Baralyme became more effective and between 55°F and 85°F Sodasorb (Type A) averaged only 30% longer durations. A detailed summary of results is given in Table 2.

(3) In reference 4, Smith conducted low temperature performance tests for the U.S. Navy. The canister from a USN MK VI semi-closed circuit scuba was used. The canister was immersed in a water bath, and the inlet gas was heated and humidified before entering the canister to simulate human respiration. The test parameters were as follows:

(a) Depth: 0 FSW

(b) Canister type: Cylindrical with annulus

(c) Amount of absorbent: 2722 gr. (6 lbs)

(d) Type of gas flow: pulsatile

(e) Gas flow rate: 30 LPM with 3 liter tidal volume and 10 BPM

(f) Gas mix: Test #1- 94% N_2, 2% O_2 and 4% CO_2
Test #2- 94% He, 2% O_2 and 4% CO_2

(g) Gas temperature into canister: 98.6°F

(h) Gas humidity: 100% R.H.

(i) Water bath temperature: 35°F and 65°F

(j) Breakthrough Value: 0.5% CO_2 measured at canister outlet

The results showed that Sodasorb (Type A) outlasted Baralyme in Nitrogen by 110% at 35°F, and 40% at 65°F. In Helium, Sodasorb (Type A) lasted 90% longer than Baralyme at 35°F, and 30% longer at 65°F. Both absorbents had a 15% reduction in breakthrough times when using Helium versus Nitrogen as the carrier gas.

(4) In reference 5, T.C. Wang conducted surface experiments to determine the CO_2 absorption capacity of High Performance Sodasorb compared with Medical Grade Sodasorb. A small laboratory canister was

used with very low gas flow and CO_2 add rates. The carrier gas was not heated before entering the canister. Test parameters were as follows:

(a) Depth: 0 FSW

(b) Canister type: Cylindrical

(c) Amount of absorbent: 10 grams

(d) Type of gas flow: Continuous

(e) Gas flow rate: 0.61 LPM

(f) Gas mix: 99% Air, 1% CO_2

(g) Gas temperature into canister: Test #1- 70-75°F
Test #2- 50-55°F

(h) Gas humidity: Test #1- 75-85% R.H.
Test #2- 65-75% R.H.

(i) Water bath temperature: Test #1- 70-75°F
Test #2- 50-55°F

(j) Breakthrough Value: 0.5% CO_2 measured at canister outlet

Results showed H.P. Sodasorb to be 70% more efficient than Medical Grade Sodasorb between 70 and 75°F, and 300% more efficient between 50 and 55°F. These tests were run under optimum conditions of low gas flow and low CO_2 add rates. In the discussion of humidity effects a comparison of Baralyme and H.P. Sodasorb is made with much higher gas flows and CO_2 add rates. The corresponding difference in bed efficiency is much less. It is obvious from the variety of tests cited herein that CO_2 absorbent beds react quite differently under various gas flow and CO_2 add conditions.

Conclusion: Both types of Sodasorb are up to 60% more efficient than Baralyme in water above 60°F, and up to 300% more efficient in water approaching 35°F.

C. Caustimity

The potential causticity of CO_2 absorbents has long been of concern to the diver. The U.S. Navy originally adopted Baralyme as its sole UBA CO_2 absorbent because of causticity considerations. Baralyme was

initially manufactured in pelleted form and contained no alkali hydroxides as does the granular Baralyme in use today. Sodasorb was eliminated from consideration because of the alkali metals it contained. However, since alkali metals were eventually added to Baralyme to increase CO_2 absorption capacity, the caustic potential became theoretically the same for each absorbent.

Caustic potential is a function of the amount of alkali hydroxides present and the solubility of the absorbent in water. A test conducted by D.D. Williams in reference 6 investigated the caustic potential of Sodasorb (Type A) and Baralyme. The caustic strength of one liter of each absorbent flooded with 100cc of water at 68°F was determined. The results showed Baralyme to be approximately 150% more caustic than Sodasorb (Type A) when allowed to reach equilibrium solubility. This result is due to Baralyme having a slightly higher water solubility than Sodasorb. However, both solutions were too alkaline to be considered safe, and each represents a potential hazard to the diver with a flooded canister.

This conclusion was further verified in reference 4 where the pH of the condensate in the bottom of a MK VI canister using Baralyme or Type A Sodasorb was between 10.1 and 11.2 for both absorbents after 3 hours of operation.

Conclusion: Both Baralyme and Sodasorb have sufficient caustic potential to be of concern. However, when tested under laboratory conditions, Sodasorb has less potential causticity than Baralyme.

D. Dusting

The tendency of absorbents to create dust during canister loading and pre-dive handling is another important consideration due to the caustic nature of the materials. This dust, or "fines", can endanger a diver in two ways: (1) a cloud of fines can be inhaled by the diver into his moist lungs and airways causing caustic burns; and (2) the fines are easily dissolved in a partially flooded canister where a caustic solution or mist may be inhaled by the diver.

In a test conducted for NEDU by Jean G. Smith (reference 4), the fracture mode of Baralyme and Sodasorb were observed. When subjected to external pressure and rough handling, Sodasorb particles generally cleaved into two pieces. Baralyme under the same conditions would disintegrate into many tiny fragments. Consequently, Baralyme exhibited a stronger tendency to create fines during canister loading and handling than Sodasorb.

The lack of dusting in Sodasorb granules is also attributable to a patented film coating on each granule (see reference 7). This coating does not affect the CO_2 absorption capacity but does cause fines to adhere to the granule's surface.

Conclusion: Dusting is generally less of a problem with Sodasorb than with Baralyme.

E. Humidity

Moisture generation and distribution in the absorbent bed are vital to maintaining optimum scrubber performance. In diver lung driven UBA's such as the USN SLSS MK 1 the combination of free water in the absorbent granules and the moisture from the divers breath is adequate to maintain the chemical reaction. However, in venturi driven, high gas velocity recirculators such as the MK 12 SSDS Mixed Gas Mode, maintaining adequate humidity becomes a major problem. Three independent research studies are cited to give comparative results of Baralyme and Sodasorb performance under various humidity conditions.

(1) The effect of humidity on Baralyme and Sodasorb (Type A) was investigated in reference 3. A cylindrical canister 3.25 inches inside diameter and 10.5 inches long with gas entering from the bottom was used. The only variables in the tests were water bath temperature, gas humidity and gas temperature. Two separate tests were conducted. The first with dry, cool gas entering the canister, and the second with heated, humidified gas to simulate human respiration. The test parameters were as follows:

	Test #1	Test #2
(a) Depth:	0 FSW	0 FSW
(b) Canister Type:	Cylindrical	Cylindrical
(c) Amount of absorbent	1000 gr. (2.2 lbs)	1000 gr. (2.2 lbs)
(d) Type of gas flow:	Continuous	Continuous
(e) Gas flow rate:	12.5 LPM	12.5 LPM
(f) Gas mix:	4% CO_2 in O_2	4% CO_2 in O_2
(g) Gas temperature entering canister	35-85°F	52-87°F

(h)	Gas humidity:	less than 10% R.H.	100% R.H.
(i)	Water breath temperature:	35-85°F	35-85°F
(j)	Breakthrough Value:	0.5% CO_2 measured at canister outlet for both tests	

The results of test #1, which are summarized in Table No. 1, show that Sodasorb (Type A) survived about 40% longer than Baralyme in 35°F water, and was approximately 100% more effective above 55°F using dry, precooled inlet gas. Test No. 2, the results of which are summarized in Table No. 2, showed Sodasorb (Type A) lasted up to 300% longer in the 35°F bath temperature range, and about 30% longer with the water temperature between 55 and 85°F when using heated, humidified gas.

(2) A series of surface tests using the Biomarine Industry CCR-1000 closed-circuit scuba were conducted by NEDU (reference 8). The tests were conducted with Baralyme, and Type A and H.P. Sodasorb. The gas mix was not artificially heated or humidified. Test parameters were as follows:

(a) Depth: 0 FSW

(b) Canister type: Annular with radial flow

(c) Amount of absorbent: 3629 gr. (8 lbs)

(d) Type of gas flow: Pulsatile

(e) Gas flow rate: 40 LPM (20 BPM and 2 liter tidal volume)

(f) Gas mix: 76% He, 20% O_2, 4% CO_2

(g) Gas temperature entering canister: 70°F

(h) Gas humidity: 50% R.H.

(i) Water bath temperature: 70°F

(j) Breakthrough Value: 0.5% CO_2 measured at canister outlet

The results with each type of absorbent were identical. Breakthrough times were consistently just over 4 hours. These results

further emphasize that at high CO_2 add rates, and high inlet gas temperatures, the performance of the various absorbent materials is similar.

(3) One of the most extensive series of canister evaluations ever made was conducted by the NCSL MK 12 SSDS development program (reference 9). The program was conducted to optimize the MK 12 SSDS mixed gas mode canister design. Baralyme and H.P. Sodasorb were tested in each canister configuration. The superiority of H.P. Sodasorb was demonstrated under the following test parameters.

(a) Depth: 0 FSW

(b) Canister type: Cylindrical

(c) Amount of Absorbent: 3856 gr. (8.5 lbs)

(d) Type of gas flow: continuous

(e) Gas flow rate: 170 LPM (6 ACFM)

(f) Gas mix: 80% He, 20% O_2 w/1.6 LPM CO_2 injection

(g) Gas temperature into canister: 64°F

(h) Gas humidity: 100% R.H.

(i) Water bath temperature: 55°F

(j) Breakthrough Value: 0.5% CO_2 measured at canister outlet

Baralyme lasted 4.85 hours to breakthru while the H.P. Sodasorb had a CO_2 concentration in the scrubber outlet gas of only 0.17% at the end of 10 hours. The reason for the difference in bed life was determined by placement of thermocouples in the scrubber bed. The thermocouples revealed bed temperatures between 80° and 90°F. Since gas was entering the canister saturated with water at 64°F a drastic drop in relative humidity occurred as the gas was warmed to bed temperature. This drop in relative humidity from 100% R.H. at 64°F to below 70% R.H. at 85°F has a significant effect on bed life, and accounts for the superior performance of H.P. Sodasorb. Its water content is between 14 and 19% by weight compared to only 9-14% water content in Baralyme.

Conclusion: High performance Sodasorb will operate up to twice as long as Baralyme under conditions of low humidity. Sodasorb (Type A) is equal to Baralyme under low humidity conditions.

F. Canister Configuration

The efficiency of a CO_2 removal system is dependent upon many variables including canister design. Six different canister designs were used in the tests cited in this report. Canister shape, baffle arrangements, size, length to diameter ratios and gas inlet and outlet configurations were all different. In each case Type A and H.P. Sodasorb performed at least as well as Baralyme regardless of canister configuration.

Conclusion: In all literature surveyed, Sodasorb was found to be equal or superior to Baralyme in all critical performance areas regardless of canister design.

G. Costs

When performance characteristics of CO_2 absorbents are comparable, the cost of the absorbent material should be considered. The following is a cost comparison dated July 1977 of Baralyme and Type A and H.P. Sodasorb when purchased in 35 lb. containers:

Baralyme	\$1.40 per pound
Type A Sodasorb	\$0.45 per pound
H.P. Sodasorb	\$0.75 per pound

The cost savings of Sodasorb over Baralyme are significant when used in the quantities currently purchased by the U.S. Navy. Type A Sodasorb is available from the Federal Stock System in only 2 1/2 and 5 lb. containers. H.P. Sodasorb is not yet available from Federal stocks. Both types of Sodasorb are available in 5 gallon containers from W.R. Grace Company. This container size should be incorporated into Federal stocks for practical application.

III. CONCLUSIONS

The following conclusions are repeated for each of the performance parameters:

A. Temperature: Both types of Sodasorb are up to 60% more efficient than Baralyme in water above 60°F, and up to 300% more efficient in water approaching 35°F.

B. Causticity: Both Baralyme and Sodasorb have enough caustic potential to be of concern. However, when tested under laboratory conditions, Sodasorb has less potential causticity than Baralyme.

C. Humidity: High performance Sodasorb will operate up to twice as long as Baralyme under conditions of low humidity. Sodasorb Type A is equal to Baralyme under low humidity conditions.

D. Dusting: Dusting is generally less of a problem with Sodasorb than with Baralyme.

E. Canister Configuration: In all literature surveyed, Sodasorb was found to be equal or superior to Baralyme in all critical performance areas regardless of canister design.

F. Cost: Baralyme is at least twice as expensive as Sodasorb. Considerable cost saving could be realized by fleet units that switch from Baralyme to Sodasorb. Although Sodasorb is not currently available from Federal stocks, is easily attained from W.R. Grace Co.

G. Type A and H.P. Sodasorb will perform satisfactorily in any type of Navy diving equipment. However, the High Performance grade is superior in high gas velocity, low moisture applications such as the MK 12 SSDS Mixed Gas Mode.

IV. RECOMMENDATIONS

Sodasorb is considered to be equal or superior to Baralyme in all critical performance areas including costs. Therefore, it is recommended that Type A Sodasorb and High Performance Sodasorb be unconditionally accepted for manned Navy diving service as a CO_2 absorbent material. While Medical Grade Sodasorb is also equal or superior to Baralyme, it does not offer any advantages over H.P. Sodasorb and consequently is not recommended for manned U.B.A. diving service.

V. REFERENCES

Reference	Credits
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2	T.C. Wang, Harbor Branch Foundation, "Temperature Effects on Baralyme, Sodasorb and Lithium Hydroxide", April 1975

3 Jean G. Smith, W.R. Grace Company, "Low Temperature Performance of CO_2 Scrubber Systems", 1973

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5 T.C. Wang, Harbor Branch Foundation, "CO_2 Absorbent Comparison Analyses", October 8, 1976

6 D.D. Williams, Naval Research Laboratory, "Comments on Relative Utility of Sodasorb and Baralyme as CO_2 Absorbents in UBA Equipment", 6130-501A:DDW:cmc, 2 October 1970

7 W.R. Grace Company, "The Sodasorb Manual of CO_2 Absorption", 1962

8 J.R. Middleton, NEDU, "T&E Department Memo on Tests of Biomarine CCR-1000", Oct 1976

9 G.W. Noble, NCSL, "MK 12 SSDS Recirculator Canister Test, Hydrospace Laboratory", Note 23-77, 11 Aug 1977

VI. APPENDICES

Table 1

Table 2

Table 1. Summary of Breakthrough Times and Temperatures for Use of Absorbents* with Dry, Precooled Gas

Bath Temp. (°F)	Sodasorb (Type A) Time (hrs)			Baralyme Time (hrs)		
	0.5% CO_2	1.0% CO_2	Max. Temp. (°F)	0.5% CO_2	1.0% CO_2	Max. Temp. (°F)
35	1.8	2.25	61	1.3	1.6	59
45	1.6	2.25	71	1.1	1.5	71
55	2.2	3.0	75	1.25	1.8	77
65	2.9	3.7	84	1.2	1.75	83
75	3.4	3.8	90	1.8	2.5	90
85	3.3	3.75	99	2.2	2.8	98

* Constant wt. of 1000 gr charged to canister.

Table 2. Summary of Breakthrough Data For Absorbents* with Humidified Gas

Bath Temp. (°F)	Sodasorb (Type A) Time (hrs) 0.5% CO_2	Sodasorb (Type A) Time (hrs) 1.0% CO_2	Sodasorb (Type A) Max. Temp. (°F)	Baralyme Time (hrs) 0.5% CO_2	Baralyme Time (hrs) 1.0% CO_2	Baralyme Max. Temp. (°F)
35	2.6	3.8	86	1.3	1.7	91
45	3.4	3.9	92	1.9	3.2	97
55	3.4	3.9	96	2.4	3.4	95
65	3.8	4.5	102	3.2	3.9	103
75	4.3	5.0	113	3.6	4.2	109
85	4.6	5.2	112	3.5	4.4	115

* Measurements made with filled canister; results normalized to constant weight basis of 1000 gr.